

The Failure of the Jagir-System

A Game-Theoretic Approach to the Fall of the Mughal Empire

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Abstract: In this paper, I investigate how the incentive-structures in the revenue-system of the Mughal Empire contributed to its disintegration. I develop a principal-agent model with multiple periods, to capture the situation that existed in the Mughal Empire. Using this model, I show that the Incentive-structure created by the system made it efficient for the agents to waste their resources on unproductive measures, and to refrain from investing. The deficit of state funds that comes thereof results in a weak emperor being unable to hold the empire together, and the agents will then declare themselves independent. Comparing this outcome with historical facts, I draw the conclusion that this was the primary reason for the rapid collapse of the Mughal Empire, and that if the emperors wanted to secure its integrity, they would have to make a credible commitment to reducing their power by allowing the establishment of a politically influential nobility.

Contents

1. Introduction	4
1.1 Purpose	4
1.2 Previous Literature	4
1.3 Method	6
2. Historical background	7
2.1 Introduction to Section Two	7
2.2 Short History of the Mughal Empire	7
2.3 Mughal Provincial and Revenue Administration	9
3. The Model	13
3.1 Introduction to Section Three	13
3.2 Basic Lineup of the Model	13
3.3 The Model with Infinite Periods	18
3.4 The Model with Finite Number of Periods	20
4. Analysis	22
4.1 Introduction to Section Four	22
4.2 The Failure of the Jagir-system of Revenue Collection	22
4.3 A Possible Solution to the Incentive Problems in the Jagir-system	26

5. Conclusion	29
5.1 Summary	29
5.2 Concluding Remarks	30
6. Appendix	31
6.1 Description of Graphical Illustrations	31
6.2 Decision-tree for Three Periods	32
6.3 Table of Payoffs for Three Periods	33
7. Sources	34

1. Introduction

1.1 Purpose

The subject of how the institutional framework of a society influences its historical development is a subject that has received much attention in various academic studies. However, the study of how a particular institution creates a particular historical outcome can only be of value to us, if we also can understand the mechanism which creates the specific conditions that lead to this outcome. If we can gain understanding of this relation, we can add an important explanatory variable to any historical argumentation, which will provide us with a method of better understanding the world in which we live.

One historical process, which has often been the subject of this kind of analysis is the decline and eventual fall of the Mughal Empire in India. Especially its exceptionally rapid collapse, from the dominant power in South Asia, to nothing more than a small plot of land in less than 30 years, has given rise to various theories concerning the reason for the decline.

The objective of this thesis will be to create a model which can be used to analyse the situation during the later days of the Mughal Empire, and based on it, try to find an explanation to the very rapid geographical disintegration of the empire, and also, to see if there could have been any way to prevent the decline. Particularly, I am interested in examining how the revenue-system and the thereto connected provincial administration of the Mughal Empire, based around a concept called the Jagir, contributed to this turn of events. The question which I will attempt to answer is thus: How did the Mughal institution of the Jagir contribute to the collapse of the empire, and how could the system have been revised to avoid such a situation?

1.2 Previous Literature

The study of this subject is also interesting as the rapid decline of the empire is even more exceptional, given the fact that in 1707, the Mughal Empire was not only the arguably most powerful Muslim

empire in the world, but it also had a strong economy. Particularly a cotton industry that supplied high quality cloth to, among others, the British (Majumdar et al. 1960, p. 572-573), and even though North (1993, p. 10) argues that distortions in the labour market due to the Indian caste system prevented economic growth, it must be concluded that the Mughal Empire was in no way underdeveloped, or lacking the resources and potential to become a major factor on the world political stage.

As earlier mentioned, the rapid decline of the Mughal Empire has been the subject of several studies, and has given rise to various theories as to the circumstances which brought the apparently successful empire to collapse. Athar Ali (1966) argues that the massive appointments of noble titles to persons not connected by ethnicity or religion to the Mughals resulted in a crowding out of the loyal Islamic Mughal nobility, which destabilized the Empire, by reducing the capacity of the army and creating a situation where rivaling political entities struggled for influence. Richards (1976), however, points out that the crowding out in itself was not the cause, but rather the Mughals' inability to cope with disloyal noble subjects of non-Mughal ethnicity, which in the end caused previously loyal subjects to revolt as well.

Debs (2007a) uses the framework of game-theory and principal-agent models, to examine how the Jagir-system can be connected to the decline of the Mughal Empire, by arguing that the emperor used shuffling of delegates and inefficient public investment as a tool for remaining in power, as this will create a will amongst the delegates for replacing the emperor. Debs (2007a) differentiates between good and bad types of emperors and delegates, and claims that by using the aforementioned tools, the emperor can reduce the payoff of the delegates to such a degree that both bad and good types wish to replace him. However, the general public cannot observe the type of the delegate, and will thus be reluctant to support a revolt, as it might lead to a bad type getting crowned emperor, and thus, any calls for revolt will not be supported by the people, and thus fail. The inefficiency created by this system did, however, according to Debs (2007a), contribute to the eventual decline of the Empire.

In a similar way, this thesis strives to explain how the system created economically inefficient resource allocations, however, in contrast to Debs (2007a), this thesis, instead of looking at the

incentives for the emperor to make inefficient investment decisions, focuses on the incentives of the agent in the provincial administration, and how the flaws therein created inefficiencies. Especially, I find that Debs's (2007a) assumption that the central government remained strong throughout the period does not coincide with the facts provided by historical narratives of the events during the later days of the Mughal Empire.

Debs (2007b) further examines how the strength of a ruler can affect economic efficiency, and in particular, how it affects investment. In the model presented, which builds on the model presented in Debs (2007a), Debs (2007b) allows for the emperors to have varying strength, and then relates an emperor's strength, and thus his ability to resist an insurrection, to his will to allow investment by the delegates. It is assumed that by observing a delegate's investment decisions, the populace can discern if he is good or bad. Thus, while a strong emperor will allow investment, a weak one will shuffle delegates who invest, as he does not want the populace to know the type of the delegate. If they did know, Debs (2007b) argues that they would support a revolt by a good delegate against a weak and bad emperor. This would then prevent any form of investment in the case of a weak emperor.

This does, however, not explain the numerous provinces that actually broke free from Mughal rule, as in the model presented by Debs (2007b), no revolts would occur, as any weak emperor would consistently shuffle any delegate who makes investments to prove his type. Thus, I think there must have been some further aspect of this, which created an incentive for the provincial governors to revolt against the Mughal Emperors.

1.3 Method

For the analysis of this subject, I will use a game-theoretic approach. The model that I will use will be a two player principal-agent model, with multiple periods. In every period, the agent must distribute an initial endowment between the players, which will then decide what payoffs the players are contending for. Following this, the agent in a further step chooses if he wishes to defect or not, which will then trigger a response from the principal. The principal's responsive strategy will depend on his cost of action, which is decided by his type. This type is drawn from a random distribution, so that in every

period, there is a probability that the type will change. Further, I make the initial endowment dependent upon what strategies were previously played, which forces the players to have foresight when it comes to their choice of strategy. Then, I will analyse the model under two different circumstances, which will be represented by changing the assumptions regarding the number of periods. The model and how it works is further discussed in section Three.

The model is designed to recreate, in a much simplified state, the situation persistent in the Mughal Empire during the period in question. For this, I have used various secondary sources that deal with the history and politics of the Mughals, which will be further discussed in section Two. The historical facts that I have derived from these sources have then been compared with the outcome of the model, and based on this, I have attempted to analyse how this model can be used to explain the historical situation.

2. Historical Background

2.1 Introduction to Section Two

This section aims to give a short historical background to the Mughal Empire, to familiarize the reader with the subject of this thesis. Thus the first part of the section will give a brief history of the Mughal Empire, from its origins in the Timurid Empire of the 14th century to its eventual collapse and the final expulsion of the last emperor in 1857. The second part will describe the most important aspect of the Mughal administration for this thesis, which is the revenue-system, and the system of provincial administration.

2.2 Short History of the Mughal Empire

The founder of the Mughal Empire was called Babur, and he was a descendant of Timur Leng (Tamerlane), the 14th century Turko-Mongol conqueror, and possibly, he was also a descendant of Genghis Khan (Majumdar et al. 1960, p. 425). In fact, the name Mughal alludes to this decent, as it

basically means “Mongol”. Babur only controlled marginal holdings in Central Asia, and after several failed attempts to capture Samarkand from the Uzbek Khans, he instead turned his attention towards India. After defeating the Afghan Lodis, who were in control of Delhi at the battle of Panipat in 1526 (Keay 2000, p. 292-293), much of northern India came under Mughal control, and gave Babur a powerful base to continue his conquests from.

During some tumultuous years following the death of Babur in 1530, the Mughals again lost control over much of their Indian domains to a certain Sher Khan Sur, to whom I will return later in this narrative, due to his importance as regards the administrative system of the Mughal Empire (Majumdar et al. 1960, p. 440). However, Sher Khan Sur’s reign did not last more than five years, and Babur’s son Humayun managed to regain his father’s domains with the help of the Safavid Persians (Keay 2000, p. 308-309), and establishing the Mughals as the foremost power in India.

The Mughal Empire continued to expand its domains over northern and central India during the following centuries, especially under the reign of Akbar (1556-1605). Akbar’s reign was particularly important, as it was during his reign, that many of the institutions that were partially responsible for the success of the Mughal Empire were set up, and he expanded the borders of the Empire greatly. During the reigns of Akbar, his son Jahangir and his grandson Shah Jahan, the empire reinforced its position in India, controlling all of the northern part of the subcontinent.

Thus, when in 1658 the emperor Aurangzeb ascended the throne, he was by far the most powerful man in the area. However, where his predecessors had aimed at consolidating the empire won by Babur and enlarged by Akbar, Aurangzeb sought to expand it, something he made very clear by assuming the name Alamgir, which can be translated as “world-conqueror” (Richards and Johnson 1996, p. 165). And true to his name, Aurangzeb was an ambitious ruler, and he expanded his power both by regaining control over the Bengal, and defeating the hostile Ahoms (Richards and Johnson 1996, p. 165-168), but also campaigned extensively in the Deccan during the last decades of the 17th century, and thus forged most of southern and central India to the Empire as well (Kulke and Rothermund

1992, p. 205). When Aurangzeb died in 1707, the empire was at its greatest extent, controlling the entire subcontinent except the southernmost tip.

However, despite the apparent success of Emperor Aurangzeb “Alamgir”, his reign was a turning-point. His son, Bahadur Shah, who claimed the throne after a short struggle, ruled for no more than five years, and his death was followed by yet another power-struggle between the sons of the dead emperor (Majumdar et al. 1960, p. 527). This was followed by a string of short-lived emperors, who often neglected the military, infrastructure and administration, and who often were mere puppets in the hands of various influential persons at the imperial court, especially the Saiyid brothers (Majumdar et al. 1960, p. 528-530). This is also emphasized by Keay (2000, p. 364-367). This tumult resulted in several outlying provinces declaring themselves independent, by provincial administrators not handing the land back to the Emperor, as was the custom, and stopped heeding to imperial commands (Richards and Johnson 1996, p. 263), in addition to losses suffered at the hands of the Marathas, who were a rising confederation of states in western India. By the time the Persian ruler Nadir Shah captured and sacked Delhi in 1739, the area under imperial control had been reduced to the capital and its immediate surroundings.

The Mughal Emperors remained in power in Delhi until the last one, Bahadur Shah II, was expelled by the British in 1857, after siding with the rebels during the Sepoy rebellion (Keay 2000, p.439-440) , but his rule was only nominal. Although it retained its imperial title for over one and a half century more, the Mughal Empire fell with Aurangzeb in 1707.

2.3 Mughal Provincial and Revenue Administration

For an empire the size of the Mughal Empire, it is an impossible feat to have a centralized government where the emperor himself controls the entire expanse of land. Thus, a system of provincial administration existed, which was designed to relieve the emperor of the administrative burden, while still retaining control, even over the more distant corners of the empire.

The base of this system was the Jagir. As the revenue base was primarily agricultural output, it was important that the agricultural land was properly overseen, and that the emperor could have an official in the area to collect the revenue. The answer to this was the Jagir. The Jagir was a plot of land, usually quite sizeable, to which a noble, or Jagirdar, as they were called, was assigned as administrator. The noble was then supposed to collect revenue from the land, of which a certain amount was supposed to be forwarded to the emperor, while the noble was allowed to keep the rest for personal consumption (Majumdar et al. 1960, p. 560). Obviously, it was then also within the noble's responsibility to make sure that the land was cultivated as effectively as possible, in order to maximize the revenue that could be extracted from it. It was also part of the noble to supply a number of warriors to the service of the Emperor (Kulke and Rothermund 1992, p. 201). These warriors were primarily cavalry, and their numbers were great, possibly up to 300 000 men (Keay 2000, p. 327). Thus, the Jagirdar was not only responsible for supplying the emperor with income, but also to provide him with warriors for his army.

On paper, it seems as though the Jagir-system worked reasonably well. It produced a steady flow of revenue for the emperor's coffers, supplied the imperial army with thousands of warriors, and yet, with the exception of the dynastic struggles that seemed invariably to follow upon the death of the former emperor (Kulke and Rothermund 1992, p. 203), the empire remained fairly stable.

However, the Jagir-system contained some issues, that were inherently complicated, and which would prove fatal for the empire in the long run. Already Sher Khan Sur had noted that this mode of revenue collection was flawed (Edwardes and Garrett 1995, p. 168), and he invented a new system, in which the noble, instead of collecting part of the land revenue for his private consumption, was given a set salary by the state. This system operated still under the reign of Akbar. However, this system was not popular among the nobles who administered the provinces, who much preferred the old Jagir-system, primarily because they could then directly influence the size of their income, by pressuring the peasants under their rule to pay higher taxes.

One particular peculiarity of the Jagir-system was that the title of Jagirdar was not hereditary (Majumdar et al. 1960, p. 555). Instead, the emperor assigned anyone he deemed fit to the position of Jagirdar, and he could also remove a Jagirdar from his domain whenever he wished so. This meant that a Jagirdar was more of a governmental official title than a definition of the standing of one's family, which was made even clearer by the fact that the nobility of the Mughal Empire hailed from all the various peoples living in the empire, not only the ethnical Mughal elite, and on some occasions, even Europeans were given Jagirs (Majumdar et al. 1960, p. 555). Thus, also people who had no other bond to the Mughals than a purely official one, were given high-ranking official positions in the provincial administration.

The system worked in such a way that a noble could hold a given area of land for a maximum of one lifetime. After he died, or was reassigned to another position, or simply taken out of office, the Jagir and its associated resources went back into imperial possession (Edwardes and Garrett 1995, p. 172). The emperor then redistributed the land to a new noble from another family, who got it for, at longest, until his death. This meant that nobles were not tied to any particular land, but only to the court. Neither was the son of a nobleman guaranteed a noble title, but instead, he had to earn the favour of the emperor to be awarded the same privileges that his father had. This was also most likely the intention. As it would, as Debs (2007a, p. 20) also notes, be costly not to have any land under the Jagir-system, as this was the primary source of revenue for the noble Jagirdar class, it would always be in their interest to be assigned to a Jagir. Thus, the system could be seen as a means by the emperor to keep the nobles loyal to him, as their well being was entirely dependent on the emperor assigning them a Jagir, from which to collect revenue. This dependence of the nobility upon the emperor, in combination with its heterogeneity as regards ethnicity and interests, did, according to Majumdar et al. (1960, p. 555), prevent the nobility from attaining any substantial political power as a class. The Mughal Emperors acted as absolute monarchs (Majumdar et al. 1960, p. 554), so it was thus in his interest to restrict the political power of other groups and persons.

Historically, the Jagir-system did prevail as the primary form of revenue system throughout the history of the Mughal Empire. As I previously mentioned, several rulers of the period, including Sher Khan

Sur and Akbar, did not trust the efficiency of the Jagir system, and instead tried to implement a system where the Jagirdar did not collect the revenue himself, but merely supervised it, receiving a salary from the state. Their motive for this seems to have been that they thought that there was a risk that Jagirdars would become too powerful, as they were the de-facto rulers of the Jagir (Edwardes and Garrett 1995, p. 168). They attempted to change it, but it was popular among the nobility, so a reformed system was never implemented, and any attempts were given up after the death of Akbar (Edwardes and Garrett 1995, p. 169).

Problems with the Jagir-system did also start to surface very soon after Akbar's regime which several authors have also noted. One such issue was the so called "False Musters" mentioned by Irvine (1903, p. 45). What this meant, was that on the occasions when the local nobles were supposed to make a muster of the forces that they were to supply to the emperor in case of a war, the nobles filled out the ranks of real cavalymen by putting what Irvine calls "needy idlers from bazaars" (Irvine 1903, p. 45) on a horse, and counting them as soldiers. Apparently, some nobles also lent each other extra soldiers, to reach the required amount, meaning that some warriors may have been counted twice. This was, of course, also economically beneficial for the nobles, as the costs for keeping a contingent of warriors armed and ready could thus be reduced. This behaviour obviously meant that the Imperial army would have, on paper, appeared much more powerful and numerous than it really was, and although attempts to stop the false musters, such as branding horses and making lists of all warriors, even including their physical appearance, so that no one else could take their place, were made, the central authorities were unable to prevent this type of abuse of the system (Majumdar et al. 1960, p. 503-504).

Another problem, and arguably an even graver one, was that there was extensive cheating when it came to the revenue collection and land cultivation of the Jagirs. What often happened was that the Jagirdars wasted all the resources they could get hold of on various luxuries, without investing it in any form of productive enterprises (Majumdar et al. 1960, p. 555). This meant that whatever income the nobles received, they wasted during their lifetime, as, in the words of Edwardes and Garrett (1995, p. 172) "Any wealth which an officer contrived to accumulate by his own efforts became at his death the property of the Emperor, and the most that he could expect was that the Emperor would grant an

adequate subsistence allowance to his family after his demise, and that he would confer suitable appointments on his sons”. Due to this behaviour, Jagirs had lower productivity in reality than they ought to have, resulting in much decreased tax revenues being earned by the state. There was, as Edwardes and Garrett (1995, p. 171) calls it, an “...embargo laid upon thrift...”

3. The Model

3.1 Introduction to Section Three

In this section of the thesis, I will go through the model, upon which I will base my analysis. The first part of the section will introduce the basic features of the models, as well as state the definitions of the variables included, and the basic assumptions that I make. In the following two parts, I will then go through how the model would work under varying conditions. Especially, this regards the definition of the length of the game, as the number of periods is a very important factor for determining the final outcome in the game. Thus, I will first illustrate the outcome of the model in a situation where there is no known finite number of periods, but where the game will, theoretically, go on indefinitely. Then, I will go through the game once again, however, this time with a set number of periods.

3.2 Basic Lineup of the Model

The model I will use to illustrate this situation will constitute a simple principal-agent type game with two players, called Jagirdar (J) and Emperor (E). In this model, I will simplify the case, so that there is only one Jagir, although in reality, there would have been a substantial amount. This can be motivated by the fact that the situation and demands facing each Jagir would have been relatively similar, so any course of action that is optimal for one Jagirdar, will be so for the rest as well. Further, we assume that every Jagirdar tries to maximize the utility of his entire family, not only the individual who is currently in control of the Jagir. This is also a reasonable assumption, as the culture in which this scenario takes place was rather clan-oriented in its nature (Madani 1993, p. 86).

The game lasts for a total of n periods, where each period represents one generation. Once again, I make an assumption to simplify the model, so that every generation of Jagirdars and every generation of emperors is simultaneous. I here disregard the possibility of the shuffling of official titles, discussed by Debs (2007a), as from a model perspective, the end of a family's control of a Jagir will be equivalent to shuffling. Thus, the players will be consistent throughout all periods of the game.

In the first period, J receives a Jagir, which has an inherent value of $H > 0$. H could be defined as the total utility that J gets from controlling the province, when there are no costs or distortions. H can thus be seen as the revenue gained from the province in every period. Of this value H , a certain amount, denoted τ , will be forwarded to the state. This τ represents both taxes paid to the emperor, and other costs associated with creating value for the empire, such as equipping warriors and investing in production, and thus it is not available for consumption for J . This factor τ is constant, relative to the other factors in the model, so it can be seen as a set percentage of H . For τ , I assume that it is bigger than zero, but as it is a portion of H , it must be smaller than that factor, so formally:

$$H > \tau > 0$$

Every period begins with J making a choice of how to distribute the value H created at the start of the period. We call this step 1. He could either Produce (P), or Waste (W). To chose P means that he does what is generally expected of him, namely to utilize the resources at his disposal to produce revenue. Utilizing the province in this manner will result in a new H being generated for distribution in the next period, discounted by a factor $(1 + \delta)^{j-1}$, as the net present value of future revenue decreases. All variables are discounted by the same factor, however, so their relative proportions will remain constant over time. In addition to this, J will also provide the emperor with the correct percentage of the revenue as a tax, which I will denote τ_r . Thus, J will keep $H - \tau_r$ for consumption. If, however, J chooses to play W , he will waste the resources at his disposal on luxuries and goods for private benefit, and refrain from producing. He will now only provide the emperor with a false tax, denoted τ_f , which is lower than τ_r , allowing J to keep $H - \tau_f$ for consumption. Obviously, $H - \tau_f > H - \tau_r$.

Further, as J does not utilize the production possibilities of the province, but uses the resources for unproductive luxuries, no new H will be generated for the next period. This means that in the next period, the province will generate 0 revenue, irrespective of what J plays. J will still need to provide E with the tax though, meaning that in any period following a period where J played W , J will get a negative revenue. Only by playing P can a new H be created. This does, however, mean that if J played W in period $j = 1$, a new H can earliest be distributed in period 3, given that J played P in period 2. E cannot directly observe whether J plays P or W , and will accept the tax, no matter whether it is τ_r or τ_f . However, I also make the assumption that:

$$H - \tau_f < H - \tau_r + (H - \tau_r)/(1+\delta)$$

That is, that the difference between τ_r and τ_f cannot be so large that $H - \tau_f$ is as large or larger than $H - \tau_r$ in two periods. This also does seem reasonable, as too huge a difference would catch the attention of the emperor.

After having chosen P or W , J then makes a choice of whether to Defect (D), which implies that he declares himself independent as the ruler of the area formerly constituting the Jagir, and claims all of H for himself, or to remain loyal (L), in which case he remains a vassal to the emperor. I will call this step 2. Thus, in practice, J has four possible strategies available to him: (P,L) , (P,D) , (W,L) and (W,D) . If he plays L in step 2, this implies that the distribution of H made in step 1 holds, and the period ends. A new period then begins, in which the players distribute the eventual H created in the preceding period between them.

If, however, J plays D , E will be forced to react to this in a new step, called step 3. The strategies that are available to E are Fight (F), which will induce a cost on the emperor, but give him back control of the province, and Rest (R), in which case he does not take action against the rebellion, and loses control of the province. In theory, step 3 always occurs, no matter if J plays D or L , but when it is L , E will always play R in step 3, no matter what the other circumstances are, so to make the model more easily comprehensible, this step will henceforth be omitted from the discussion.

The cost induced on the emperor for punishing a rebellious Jagirdar will henceforth be denoted C . This C represents the effort that E will have to make in order to defeat J , and quell the rebellion. Thus, E will always regain control of the province if he plays F . This means that whatever strategies are chosen in step 3, they will always end the game. If E plays R , all provinces revolt, and the empire collapses. If E plays F , J will be killed, effectively terminating the game.

The payoff that E will receive from fighting will be:

$$-C + \tau$$

J , however, who is killed, gets a payoff of 0. If he plays R , on the other hand, he will receive 0, while J keeps all of H for himself. Thus, E 's choice of strategy must depend on the relation between C and τ . If $-C + \tau > 0$, it will be optimal for E to choose strategy F . If $-C + \tau < 0$, it will be optimal to play R , as the cost of fighting will be higher than the income generated by the province. (As E compares the possible payoffs $(-C + \tau, 0)$).

Now, I assume that there are two types of emperors, namely strong (s) and weak (v). The strength of the emperor will affect the cost of playing F . Thus, there are two different versions of C , C_s and C_v , with the relation $C_s < C_v$, implying that the cost of fighting is higher for a weak E than for a strong one. The reason behind this is that it can be assumed that a strong emperor has a certain amount of power and authority irrespective of his resources. A weak emperor, on the other hand, who lacks this authority, will have to amass more resources in order to attain the same level of effort as the strong emperor. Further, I also assume that a new C is drawn from some random distribution. Then, a new C is drawn every generation, so that in every period, there is a certain probability that the type of emperor will change. I also make an assumption that the emperor's type is publicly known from the start of each period, i.e. J can always observe whether E 's cost of punishing defectors is C_s or C_v . This assumption is also reasonable, due to the fact that the Jagirdars held a relatively important position in the empire. They would thus be able to discern, based on the actions and policies implemented by the emperor, whether he was authoritative or the puppet of some other influential character at the imperial court. As a matter of fact, the emperor's central position within Mughal society would allow most

people who could observe the emperor's actions to be able to judge whether he was a weak or strong ruler.

To be able to predict E 's choices, assumptions regarding the relationships between C_s , C_v , τ_f and τ_r will have to be made. I assume the following relationships:

1. $C_s < \tau_f < \tau_r$
2. $\tau_f < C_v < \tau_r$

What this means in practice is that E 's ability to punish defectors depends on his type, and on what strategy J employed in step 1. Following the assumption that E 's decision to play F is conditional on $-C + \tau > 0$, It can be deducted that a strong emperor always punishes, as:

$$-C_s + \tau_i > 0; i = f, r.$$

If E is weak, this means that $-C_v + \tau_f < 0$, while $-C_v + \tau_r > 0$, implying that a weak emperor will only punish if J played P in step 1 of the period in question. As a result of this, J will only play D in cases when E is weak, as he knows that E otherwise always will punish, no matter what strategy he played in step 1.

In short, the game will then play out as follows:

Step 1: J chooses P or W , thus distributing H accordingly.

Step 2: J observes the strength of the emperor, and chooses D or L accordingly. If L , the distribution made in step 1 is realized, and period 2 starts with step 1; if D , step 3 happens.

Step 3: E observes the possible payoffs, and chooses strategy F or R accordingly. The outcome of the chosen strategies is realized, and the game ends.

3.3 The Model with Infinite Periods

This is then the model upon which the analysis of this thesis will be based. I will now present cases for what outcome this model produces, when one analyses the various possible scenarios that are available.

As earlier discusses, both players are consistent throughout all periods, so that it is the same players that face each other in every period of the game. These players will then attempt to maximize their utility over all n periods, for which the game lasts. For this first example, I will assume that $n = \infty$, which means that there is no finite number of periods, but the game will continue indefinitely, unless J defects. This is primarily for the sake of illustrating the mechanics of the model, but one can also argue that it is unlikely that any empire, when it is established, is predestined to last for a set number of generations, which is known by all members of society. The players therefore do not know which period will be the final one, so they will play the game as though it had no finite n . This will always be the case when there is a high probability for a next period, which is obviously the case here.

What would then be the equilibrium outcome of such a game? To find this, I will go through the game one step at a time. In step 1, J must choose how to distribute H . he then has to make the choice between the two possible payoffs:

$$H - \tau_f \text{ and } H - \tau_r$$

As earlier stated, $H - \tau_f > H - \tau_r$, so in the short run, it would seem optimal for an individual to choose W , but following the assumption that J tries to maximize utility over $n = \infty$ periods, this is not the case, as playing W will result in no H for distribution in period 2. This can be proven by looking at the payoffs that player J would receive in period 2 in each case (assuming that the action in step 1 is always followed up by playing L in step 2). When playing P in period 1, the payoff in period 2 would be:

$$H - \tau_r + (H - \tau_i)/(1 + \delta); i = f, r$$

If W is played in period 1, the corresponding payoff would be:

$$H - \tau_f - \tau_i/(1 + \delta); i = f, r$$

Where the variable i depends on whether J played P or W in period 2. When these two payoffs are compared, what is found is that:

$$H - \tau_r + (H - \tau_i)/(1 + \delta) > H - \tau_f - \tau_i/(1 + \delta); i = f, r$$

This relation holds, following the assumption that:

$$H - \tau_f < H - \tau_r + (H - \tau_r)/(1 + \delta)$$

Thus, it will be optimal for J to play P in every period, as the loss of the revenue of one period cannot be fully negated by a higher part of revenue used for personal consumption in another period. This can be proven through iterations of the payoffs over a prolonged number of periods. (For reference, see the table in 6.3). This means that J will receive a payoff of:

$$\sum_{j=1}^n ((H - \tau_r) / (1 + \delta)^{j-1})$$

This gives J a positive, albeit declining, payoff in every period, whereas playing W in any period will result in a net loss over this and the following period of:

$$((H - \tau_f) - (H - \tau_r)) - \tau_r/(1 + \delta) < 0$$

Then, there is not any incentive for J to defect either, as playing P will result in E being able to punish, no matter what type he is, as:

$$1. \quad C_s < \tau_f < \tau_r$$

$$2. \quad \tau_f < C_v < \tau_r$$

Thus, in this type of game, the equilibrium strategy for J will be (P, L) in every period. This is, in fact, also Pareto-optimal. The model will never reach step 3, as it would be nonsensical to fight when J remains loyal, as this would only induce a cost on the emperor without any form of benefit, so E will remain passive throughout the game. I would argue that the interpretation that can be made from this is that the strategies that are equivalent of co-operating are the most efficient ones in this game when there is no finite number of periods.

3.4 The Model with Finite Number of Periods

Now, however, I will assume that there is a finite number of periods, i.e. $n \neq \infty$. This will cause some changes in the way the game eventually plays out. I will now set a finite n , but otherwise, there will not be any changes of any of the basic assumptions. The assumption that I will make in this case is $n = 2$. This is just an arbitrary number, chosen for simplicity, and the implications for the payoffs that can be derived from this hold for all finite number of periods.

J will now look at the payoffs available to him, and choose the one which maximizes his payoff over the two periods. Just like was described earlier, in the first period, the payoffs available to player J are:

$$H - \tau_f \text{ and } H - \tau_r$$

Just like in the first case, choosing to play W in step 1 of period 1, will result in a payoff of $H - \tau_f$ in that period, but due to the unproductive nature of W , no new H will be available for distribution in period 2. He will, however, be forced to pay a tax to the emperor, so the payoff in period 2 would be negative. Choosing P would give a payoff of $H - \tau_r$, but generates a new H to distribute in the next period.

As was earlier shown, playing P is always the best option when there are subsequent periods, as the revenue lost will not be negated by higher revenue in period 1 due to the assumption:

$$H - \tau_f < H - \tau_r + (H - \tau_r)/(1+\delta)$$

J then has to consider the choice of whether to fight or remain loyal in step 2. If he played P , as seems most reasonable, playing D would not be an option, as E will then be able to punish by playing F , no matter what type he is, and J would receive a payoff of 0. Thus, it can be concluded that in period 1, J will always play (P, L) .

Then, period 2 will have to be considered. Here, the outcome changes a bit. As this is the last period, one thing which was very important in the previous period is made insignificant, namely the fact that one has to consider the revenue generated in subsequent periods. J is thus indifferent towards whether

a new H would be generated, as it would only come to existence in the following period, which here does not exist. Thus, J chooses between the following strategies:

Playing P , earning a payoff of:

$$H - \tau_r + (H - \tau_r)/(1 + \delta)$$

Or playing W , earning a payoff of:

$$H - \tau_r + (H - \tau_f)/(1 + \delta)$$

Here, it is found that the extra income generated by supplying the emperor with the false tax in the last period, without having to worry about lost revenue in coming periods due to no investment gives the relation:

$$H - \tau_r + (H - \tau_r)/(1 + \delta) < H - \tau_r + (H - \tau_f)/(1 + \delta)$$

This means that it will now be efficient for J to play W . J will then observe whether E is strong or weak, i.e. whether E 's cost of punishing is C_s or C_v . He will then make a choice of what to play in step 2. If E is strong, he will chose to play L , as the assumption $C_s < \tau_f < \tau_r$ implies that $-C_s + \tau_f > 0$, which means that if J plays D , E will play F , as this is his best response. Therefore, J will play L , earning the equilibrium outcome of:

$$H - \tau_r + (H - \tau_f)/(1 + \delta)$$

E will in this scenario earn a total payoff of:

$$\tau_r + \tau_f/(1 + \delta)$$

This is also a Pareto-optimal equilibrium.

If, however, the emperor is weak, the assumption $\tau_f < C_v < \tau_r$ means that $-C_v + \tau_f < 0$, leading to the conclusion that the emperor would be better off playing R in step 3. Thus, when E is weak, J will play D , and E , who cannot respond, will play R , letting J earn the equilibrium outcome of:

$$H - \tau_r + H/(1 + \delta)$$

This is the highest payoff that J can reach in this game, and despite E earning a total payoff of merely τ_r in the game, this outcome is still Pareto-optimal.

Both these outcomes are the Pareto-optimal equilibria of their respective cases, and thus, it can be seen that what the final payoffs of the game will depend on E 's type in period 2 (or whatever period is stated as the final period of the game).

This is true for any finite number of n , which shows that in such a case, the optimal strategy for J will be to play (P,L) in all periods except the last, where the optimal strategy is to play W , and then, after observing E 's type, choose (D,L) accordingly. This means that the model has a sort of built-in commitment-mechanism, so that no matter situation, any attempts to play a non-co-operative strategy is punished, unless the period in which it is played is the final one.

4. Analysis

4.1 Introduction to Section Four

In this section, I will go back to the situation that was described in the historical background section, and discuss how the principal-agent model that I have laid out can be used to shed light on the situation. The intent is to, with the analytical framework of the model, discuss why the Mughal Empire disintegrated like it did, and what could possibly have been done to prevent the extremely rapid state of decline that the empire faced after the death of Aurangzeb in 1707.

4.2 The Failure of the Jagir-system of Revenue Collection

As earlier discussed, the Empire collapsed very quickly following the death of Aurangzeb, and had, within the short time-span of 30 years, shrunk to nothing more than the absolute vicinity of the imperial capital at Delhi. Given that the empire reached the height of its power during the last days of Emperor Aurangzeb, and the fact that the empire had remained relatively stable for the previous 150

years, this is quite exceptional. So what was the reason for this speedy collapse? To analyse this, we must go back to the revenue system employed by the Mughals, which was based on the division of the land into Jagirs. Especially, we will be looking into the fact that the title of Jagirdar was, as earlier stated, not hereditary. Instead, the title and all the wealth of the person who had held it previously went back to the emperor upon the Jagirdar's death, and another noble was assigned to the Jagir.

I will now look at this in terms of our model, which I outlined in the previous section. As the Jagir, and the thereto belonging noble title of Jagirdar, can only be held by the same family for one generation, before it goes back to the state, what we have is, in fact, a game which lasts for only one period ($n = 1$). Thus, when someone is assigned to a Jagir, they know that whatever resources they will gain from it, will be taken from them when they die, preventing the members of subsequent generations to benefit from it.

What this means in terms of the model, is that this is then the equivalent of the case in 3.4, with a finite number of periods, where J will play the cooperative strategy (P, L) in all periods except the last, where he will waste, and then choose whether to defect or remain loyal, depending on the emperor's type. Then, the Jagirdar (J) will try to maximize his utility over one period. This period will then, by definition, be the last period in the game, so J will play W , and then, after observing the emperors type, chose D or L .

In every new generation, a new Jagirdar, belonging to a new family will be assigned to the Jagir. Theoretically, this game with one period will then be played over and over again, with new players. Then, J will waste in every game. This will be beneficial, even when I take into account the fact that despite that the game is only one period, in reality, there would have been periods preceding it, in which an earlier J also would have wasted. This would mean that the revenue from the province would be zero, but as J wastes, he only has to pay a tax of τ_f . As $\tau_f < \tau_r$, which is what he would pay in tax if he produced, $-\tau_f > -\tau_r$, and thus, even if I would make an assumption that the strategies played by the other players in the previous period affects the current period, the equilibrium outcome holds. One must also remember that H just represents the revenue from the Jagir. By possessing an official title,

the noble would have a certain amount of wealth, irrespective of the revenue gained from the Jagir. Thus, even though the Jagir would not provide any extra revenue, the nobles would not have a negative income in total. However, this wealth would, just like any revenue collected from a Jagir, be expropriated by the state upon the nobleman's death, so there would be no incentive to do anything else but waste these resources on unproductive luxuries as well. This does not affect the model, though, as this wealth can be considered to be unaffected by the noble's eventual Jagir-administration, and the management thereof.

I would then argue that what we have is in essence a system with flawed incentives for the agents, i.e. the Jagirdars. The Jagir-system with no hereditary titles or ownership of resources therefore had as an effect that there were no incentives to invest the revenue collected from the Jagir in projects for increasing productivity, nor any incentive to save resources for the future.

A simple thought-experiment which well illustrates the dilemma could be to consider the following situation: Today, you receive \$100. You have two choices; either, you spend all the money today, or you spend half of it today, investing the rest in stocks, whose value will have doubled tomorrow. It then seems as though the most prudent choice would be to do the latter, which would give you a new \$100 tomorrow in addition to the \$50 you get today. Now, however, assume that no matter what you choose, whatever money you have left tomorrow will be taken from you. Suddenly, the first choice has turned into a decision of whether you want \$50 or \$100. The best choice in this situation is then very obvious.

This is the very same situation as the one which the Jagirdars were faced with. No matter what they did, whatever resources they did not consume within their lifetime would never become the property of their children, or grandchildren. Thus, following the assumption that individuals care about the utility of subsequent generations, they had a choice of consuming everything now, or consuming some of it, investing the rest in a project, of which someone else would reap the benefit. It would be quite naïve to assume that the Jagirdars would have been so altruistic that they would be willing to sacrifice some of their family's utility, for the benefit of some other Jagirdar, or nationalistic enough to sacrifice

it for the good of the empire. Particularly as the nobility often had no ethnical connection to the Mughals themselves, and only served them out of necessity.

This resulted in the earlier discussed situation, with the Jagirdars supplying the state with substantially lower tax revenue than would have been the case if there had been incentive-system which made it beneficial for the nobles to invest resources into furthering the productivity and revenue generated by the Jagirs. This, in its turn, led to the state running a perpetual deficit, compared to the estimated revenue. Any investments would disappear into the provincial administrator's pockets, and due to the false musters, the army was both far smaller and worse equipped than it appeared on paper. This then leads to the equivalent of step 3 in the model. As earlier stated, J will observe the strength of E , and choose which of the strategies D and L he would play accordingly. The loss of revenue and the state of the army meant that in order for the central government to keep control over the empire, they would have to rely on something else. In the model, as, it will be seen, was also the case in reality, this factor would be the strength and authority of the emperor.

In the model, what I find is that given that W was played in step 1, it is efficient for player J to remain loyal when E 's cost of punishing is C_s . However, when the cost is C_v , the revenue τ_f that the emperor will gain from fighting if J defects, is not large enough to merit the cost of punishing. Thus, when E is weak, J will defect. This means that when the one-period game is repeated with new players each time, the game will continue until a weak emperor with a cost of punishing equal to C_v is drawn from the random distribution. At that point, the current J will play strategy D in step 2, and E 's best response will be to play R , thus allowing the revolt to go unpunished.

The implications of the model also, to a large degree, coincide with what happened historically. Throughout much of its history, the Mughal Empire was blessed with strong and powerful rulers, who possessed the authority to implement their policies as they wished, and commanded much influence over their subordinates. Thus, strong rulers, such as Akbar and Aurangzeb managed to hold the empire together, through their skillful use of policies and through the strength of their characters. However, when in 1707 Bahadur Shah ascended the throne, this changed. What followed was a period of weak

and short-lived emperors, who often lacked the power and authority to implement their policies and impose their will without the support of various influential court officials, who often pursued their own agendas, instead of trying to further the cause of the Empire, which obviously was in the Emperors' interest. Thus, they were unable to respond appropriately to external threats, and perpetual internal struggles often prevented them from staying in power long enough to be able to reinforce their position.

What happened was, just like the model predicts, that the Jagirdars and other provincial administrators ceased to heed the orders of the emperor, and in practice, many became as good as independent. The emperor thus lost both the major part of his tax base, and also the main supply of men for his army, making the empire susceptible to foreign intrusions, such as the Invasion of the Persians under Nadir Shah in 1739, and internal threats, such as the Marathas, Sikhs and Rajpoots.

Thus, the model explains how this decline could happen so fast, as the imperative of Imperial cohesion to a large extent relied on the character and personal authority of the emperor. The advent of one weak emperor is then capable of causing the whole system to collapse, due to the misdirected incentives inherent therein. By changing the system to correct the flawed incentives, it could then have been possible for the Mughals to uphold imperial provinces. However, the system would then have to be designed in such a way that there would always be an incentive for producing. I will now examine how this could have been achieved.

4.3 A Possible Solution to the Incentive Problems of the Jagir-system

To answer the question how the Mughals could have reworked the incentives of the Jagir-system in such a way that producing would have been beneficial, I will turn again to the principal-agent model that I have previously outlined. The basis of the problem is obviously that the game with a finite amount of periods has got an equilibrium outcome in which it is efficient for J to waste in the last period. This makes the Empire susceptible to revolts, if the emperor's authority is weak, as J then knows that any attempts he might make to declare himself independent will be met by passivity from the emperor. This will then lead to the collapse of the empire when ruled by a weak emperor.

The first, and most obvious, solution would perhaps be to change the system to make noble titles hereditary, so that the sons of noblemen inherit their titles and their assets. The fact that there was no incentive for saving or investing, as one could not gather utility over more than one period, was the foundation of the fact that Jagirdar wasted their assets on unproductive luxuries, and abhorred investments, as they would never come to their or their children's benefit. If one now would assume that we change the Jagir-system, so that titles and assets are hereditary, there will suddenly be an incentive for the Jagirdars to invest, as the fact that productive investments allow further revenue to be collected in subsequent periods makes the payoff of such a strategy efficient. In essence, what this results in is the equivalent of the game with no finite periods. There is no set limit to the amount of generations that can inherit the assets, and as long as no one believes that a period will be the last, they will act as though there would be subsequent periods.

As I earlier discussed, in a game where there is no finite amount of periods, the optimal strategy for J is to play (P, L) in every period, as this gives a total payoff throughout the game of:

$$\sum_{j=1}^n ((H - \tau_r) / (1 + \delta)^{j-1})$$

Thus, by changing the Jagir-system in such a way that assets can be inherited by future generations of a family, it is could be possible to turn the incentives around in such a way that it is not only more profitable for the Jagirdar to produce than waste, but the increased tax revenue earned by the state will also create a situation where Jagirdars know that any attempt at defecting will be effectively punished by the emperor. Therefore, the system also forces loyalty among the noble classes, and secures the integrity and stability of the empire, irrespective of the power and authority of individual emperors' character.

Why, then, did the Mughal emperors cling to the old system? Some emperors, as already noted, did realize that the system had some inherent flaws, but besides the short-lived reforms of Sher Kahn Sur and Akbar, no attempts at improving upon the system were undertaken. The most likely reason for this is that despite its drawbacks, there was one feature of the system which the Mughal emperors were very anxious not to change, and which they seem to have been willing to accept the risks associated

with the flawed incentives, in order to keep. This was the fact that it created a dependency of the nobility upon the emperor, which otherwise would have been hard to obtain. It was only noblemen who had proven their loyalty to the emperor who would be granted the privilege of a Jagir and an official title, so any noble who were critical or did not in some other way appease the emperor, would quickly lose his title, and could not hope to be restored to his title and reassigned to a Jagir.

By allowing the nobility to develop and accumulate assets on its own, without having to depend upon the good will of the emperor, it is quite possible that a strong class of landowning nobles would have arisen, that could unite the strength to gain political influence. This would then lead to a decrease in the power of the emperor, who no longer would be able to have the last say in every decision. Thus, giving up the practice of expropriating the assets of every noble upon his death was something that the emperors were reluctant to do.

Based on this, I suspect that the implementation of the previously mentioned policy of making assets and titles hereditary could be more problematic to implement than might at first be thought. The reason for this is that it causes a problem of commitment, as the implementation of such a policy might completely lack credibility in the eyes of the nobility. Given the propensity of the Mughal emperors to act as absolute monarchs, without allowing any form of independence (not necessarily political) for the nobility, what is to keep them from seizing the private property and removing titles despite their promise not to do so? If there is no reason for the nobles to believe that the emperors will stick to their word, there is no incentive to save or invest resources in something that has a high probability of never coming to their benefit, and the wasteful and unproductive behaviour will continue. Thus, the emperor would need to be able to commit to reducing his power by allowing a politically influential class of landowning nobility to develop, in order for the flaws in the incentive system to be corrected. How this should be achieved is beyond the scope of this thesis, but it is clear that in order for the reform to have any effect, the commitment must be made very credible to the noble classes.

5. Conclusion

5.1 Summary

In this thesis, I have discussed the failure as regards the institutions of the Mughal Empire, particularly, the revenue system, and how this could explain the rapid decline of the empire following the death of Aurangzeb in 1707. For this, I developed a simple principal-agent model with two players, which presents a framework for analyzing the situation, and in particular, how incentives worked within the Jagir-system of revenue collection. The model is based on three steps, in which the agent, called *J*, first chooses a resource allocation, and then makes a decision on whether to defect or remain loyal. Following this, the principal, called *E*, makes a decision of whether to punish defectors, or remain passive. Remaining passive allows the revolt to go unchecked, resulting in the collapse of the empire, while punishing induces a cost on the emperor, which is decided by the emperors strength, but brings back control over the province to the emperor. I then examined the differences in the outcomes of the model that result from either assuming no finite periods, or a finite number of periods.

What I found was that the policy of the Mughal emperors to prevent the nobility from growing into a landowning class, by preventing them from accumulating assets over several generations, resulted in a situation where noblemen wasted all their resources on unproductive efforts, without investing anything for future interests, as they were restricted to one generation in which to maximize their utility, i.e. the model equivalent of only one period. Thus, there were no incentives for thrift or saving, but rather, wasteful behaviour was the economically most efficient for the Jagirdars. In addition to this, fraudulent behaviour as regards the mustering of military forces among the provincial nobility resulted in the strength of the army being considerably lower than what it would appear like on paper. This behaviour was found to undermine the position of the emperor to such a degree, that only a strong emperor, with much power and authority would be able to uphold order, and maintain the integrity of the empire. For a weak emperor, the costs associated with keeping the empire together

would be too high to motivate action, and this would result in a situation where landowning noblemen within the provincial administration disregard imperial orders, and start acting independently. Based on this, I argue that the loss of cohesion within the empire made it susceptible to threats from external as well as internal interest groups, which in the end led to the geographical disintegration and downfall of the Mughal Empire.

The most intuitive solution to the problem appears, at first sight, to be to allow hereditary ownership of assets. This would create an incentive for the nobility to invest, which will not only create extra value, but also allow them to spread their consumption out over an extended number of periods. This would not only result in the most efficient allocation of resources attainable by both parts, but would also contribute to keeping the empire stable, as any emperor, both weak and strong, would be able to punish defectors efficiently, thus deterring provincial nobility from playing any non-cooperative strategies.

However, I discuss the possibility that if there is no way for the emperor to make a credible commitment to enforce the policy of hereditary ownership of assets, it is likely that the policy would not have any effect. If the emperor could just retract the policy decree as he wished, something that is quite likely, given the nature of Mughal kingship, the nobility would not believe that investments would really come to the benefit of subsequent generations, and if they do not believe that there will be a next period of the game, they will attempt to maximize their utility within one, which means that there would be no difference from before the policy implementation.

5.2 Concluding Remarks

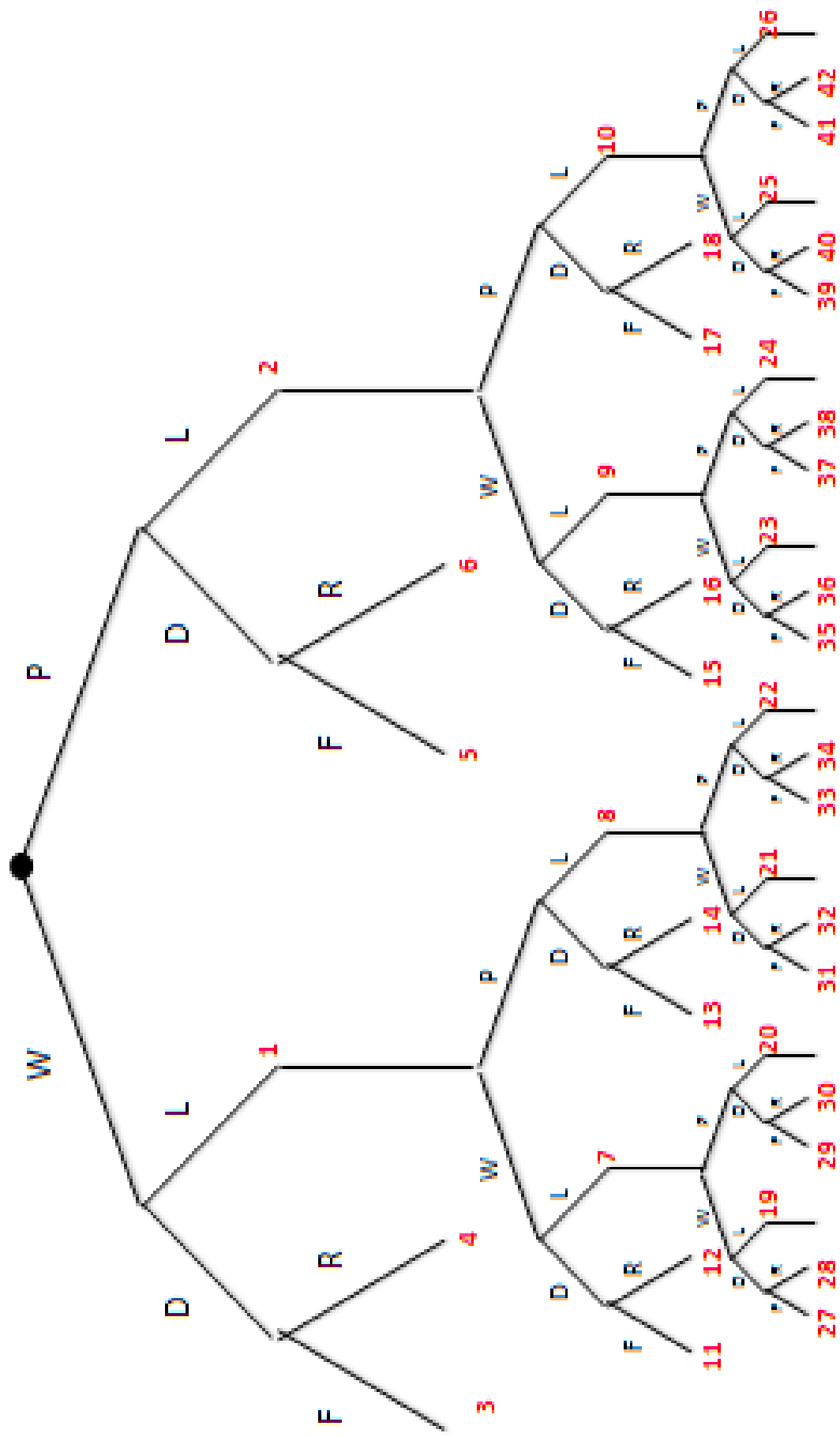
The aim of this thesis has been to analyse the downfall of the Mughal Empire in India, during the first decades of the 18th century, and particularly, how it can be linked to failures in the incentive-structure of the most important institution of the revenue-system, the Jagir. It seems as though the flaw that was the most serious, and also, one of the hardest to correct was the stern determination of the Mughal emperors to prevent the nobility from being able to organize itself as a politically influential class, as this would have created a certain balance of power, where the emperor would not as easily have been

able to enforce his will without the support of the landowning nobility. Thus, the system was devised primarily with creating dependence in mind, rather than creating an efficient resource allocation and incentive-structure. As a result, the Mughals were unable to enforce a productive system, and wasteful and unproductive behaviour on the part of the nobility drained the empire of the resources needed to keep the heterogenous society on which it was based together in the absence of a powerful leader. In the end, the system devised to ensure that all aspects of the empire were dependent upon the emperor, ultimately turned into a system where the only thing unconditionally dependent upon the emperor, was the emperor himself.

6. Appendix

6.1 Description of Graphical Illustrations

The following two pages contain a graphical illustration of the model in three periods, along with a table containing payoffs for these periods. In the first picture is depicted the decision-tree which illustrates the strategies and what combinations thereof that can be played. Every payoff is denoted by a number, in this case 1-42. Each of these numbers corresponds to a line in the table on page 31, where can be seen all the possible payoffs that the players get in each of the three periods. The payoffs are listed in numerical order, and are presented individually for each player. The payoffs denoted “Terminal”, are payoffs that are final, as they mean that they represent an outcome which ends the game. The other outcomes allow for a continuation of the game in subsequent periods, however, all payoffs are presented as they would appear if the period was the final one.



		Player	
Period	Payoff number	J	$E_i, i=s,v$
1	1	$H-\tau_f$	τ_f
	2	$H-\tau_r$	τ_r
	3 (Terminal)	0	$-Cl + \tau_f$
	4 (Terminal)	H	0
	5 (Terminal)	0	$-Cl + \tau_r$
	6 (Terminal)	H	0
2	7	$H-\tau_f - \tau_f/(1+\delta)$	$\tau_f + \tau_f/(1+\delta)$
	8	$H-\tau_f - \tau_r/(1+\delta)$	$\tau_f + \tau_r/(1+\delta)$
	9	$H-\tau_r + (H-\tau_f)/(1+\delta)$	$\tau_r + \tau_f/(1+\delta)$
	10	$H-\tau_r + (H-\tau_r)/(1+\delta)$	$\tau_r + \tau_r/(1+\delta)$
	11 (Terminal)	$H-\tau_f$	$\tau_f + (-Cl + \tau_f)/(1+\delta)$
	12 (Terminal)	$H-\tau_f$	τ_f
	13 (Terminal)	$H-\tau_f$	$\tau_f + (-Cl + \tau_r)/(1+\delta)$
	14 (Terminal)	$H-\tau_f$	τ_f
	15 (Terminal)	$H-\tau_r$	$\tau_r + (-Cl + \tau_f)/(1+\delta)$
	16 (Terminal)	$H-\tau_r + H/(1+\delta)$	τ_r
	17 (Terminal)	$H-\tau_r$	$\tau_r + (-Cl + \tau_r)/(1+\delta)$
	18 (Terminal)	$H-\tau_r + H/(1+\delta)$	τ_r
3	19	$H-\tau_f - \tau_f/(1+\delta) - \tau_f/(1+\delta)^2$	$\tau_f + \tau_f/(1+\delta) + \tau_f/(1+\delta)^2$
	20	$H-\tau_f - \tau_f/(1+\delta) - \tau_r/(1+\delta)^2$	$\tau_f + \tau_f/(1+\delta) + \tau_r/(1+\delta)^2$
	21	$H-\tau_f - \tau_r/(1+\delta) + (H-\tau_f)/(1+\delta)^2$	$\tau_f + \tau_r/(1+\delta) + \tau_f/(1+\delta)^2$
	22	$H-\tau_f - \tau_r/(1+\delta) + (H-\tau_r)/(1+\delta)^2$	$\tau_f + \tau_r/(1+\delta) + \tau_r/(1+\delta)^2$
	23	$H-\tau_r + (H-\tau_f)/(1+\delta) - \tau_f/(1+\delta)^2$	$\tau_r + \tau_f/(1+\delta) + \tau_f/(1+\delta)^2$
	24	$H-\tau_r + (H-\tau_f)/(1+\delta) - \tau_r/(1+\delta)^2$	$\tau_r + \tau_f/(1+\delta) + \tau_r/(1+\delta)^2$
	25	$H-\tau_r + (H-\tau_r)/(1+\delta) + (H-\tau_f)/(1+\delta)^2$	$\tau_r + \tau_r/(1+\delta) + \tau_f/(1+\delta)^2$
	26	$H-\tau_r + (H-\tau_r)/(1+\delta) + (H-\tau_r)/(1+\delta)^2$	$\tau_r + \tau_r/(1+\delta) + \tau_r/(1+\delta)^2$
	27 (Terminal)	$H-\tau_f - \tau_f/(1+\delta)$	$\tau_f + \tau_f/(1+\delta) + (-Cl + \tau_f)/(1+\delta)^2$
	28 (Terminal)	$H-\tau_f - \tau_f/(1+\delta)$	$\tau_f + \tau_f/(1+\delta)$
	29 (Terminal)	$H-\tau_f - \tau_f/(1+\delta)$	$\tau_f + \tau_f/(1+\delta) + (-Cl + \tau_r)/(1+\delta)^2$
	30 (Terminal)	$H-\tau_f - \tau_f/(1+\delta)$	$\tau_f + \tau_f/(1+\delta)$
	31 (Terminal)	$H-\tau_f - \tau_r/(1+\delta)$	$\tau_f + \tau_r/(1+\delta) + (-Cl + \tau_f)/(1+\delta)^2$
	32 (Terminal)	$H-\tau_f - \tau_r/(1+\delta) + H/(1+\delta)^2$	$\tau_f + \tau_r/(1+\delta)$
	33 (Terminal)	$H-\tau_f - \tau_r/(1+\delta)$	$\tau_f + \tau_r/(1+\delta) + (-Cl + \tau_r)/(1+\delta)^2$
	34 (Terminal)	$H-\tau_f - \tau_r/(1+\delta) + H/(1+\delta)^2$	$\tau_f + \tau_r/(1+\delta)$
	35 (Terminal)	$H-\tau_r + (H-\tau_f)/(1+\delta)$	$\tau_r + \tau_f/(1+\delta) + (-Cl + \tau_f)/(1+\delta)^2$
	36 (Terminal)	$H-\tau_r + (H-\tau_f)/(1+\delta)$	$\tau_r + \tau_f/(1+\delta)$
	37 (Terminal)	$H-\tau_r + (H-\tau_f)/(1+\delta)$	$\tau_r + \tau_f/(1+\delta) + (-Cl + \tau_r)/(1+\delta)^2$
	38 (Terminal)	$H-\tau_r + (H-\tau_f)/(1+\delta)$	$\tau_r + \tau_f/(1+\delta)$
	39 (Terminal)	$H-\tau_r + (H-\tau_r)/(1+\delta)$	$\tau_r + \tau_r/(1+\delta) + (-Cl + \tau_f)/(1+\delta)^2$
	40 (Terminal)	$H-\tau_r + (H-\tau_r)/(1+\delta) + H/(1+\delta)^2$	$\tau_r + \tau_r/(1+\delta)$
	41 (Terminal)	$H-\tau_r + (H-\tau_r)/(1+\delta)$	$\tau_r + \tau_r/(1+\delta) + (-Cl + \tau_r)/(1+\delta)^2$
	42 (Terminal)	$H-\tau_r + (H-\tau_r)/(1+\delta) + H/(1+\delta)^2$	$\tau_r + \tau_r/(1+\delta)$

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